[0075] As described above, the method of FIG. **7** uses body surface potential maps acquired using BSM to reconstruct epicardial potentials on the surface of the heart in order to estimate patient-specific cardiac electrical parameters of the cardiac EP model throughout the myocardium (volumetric). It is to be understood that the present invention is not limited to BSM measurements and any body surface potential (torso potential) measurements can be used. For example, the method of FIG. **7** can be performed using body surface potentials acquired from standard 12-lead ECG recordings, or with **12** leads placed in different positions selected to have the most insight on a specific myocardial electrical activity. The method of FIG. **7** can also be extended to cover cases in which multiple recordings performed at different times are combined to analyze the same phenomena, such as sinus rhythm or lead-induced front propagation in CRT. The method of FIG. **7** can also be extended such that the personalization of the EP parameters of a local region of the heart is iteratively improved using multiple phenomena (e.g., combining ventricular tachycardia and sinus rhythm). This can for instance help estimate the restitution curve (i.e. how much the action potential shortens with respect to the heart rate).

[0076] FIG. **10** illustrates exemplary results of reconstructing epicardial potentials on the heart surface from ECG measurements. As shown in FIG. **10**, image **1002** shows a visualization of reconstructed epicardial surface potentials from ECG measurements that show front propagation around a scar (no-diffusion zone), and image **1004** shows a visualization of ground truth epicardial potentials on the heart surface. FIG. **11** illustrates results of reconstructing an activation map after action potential duration regularization. As shown in FIG. **11**, image **1100** shows fitting of the template action potential function TP **1102** on a reconstructed action potential **1104**, and image **1110** shows a visualization of the reconstructed activation map on the left ventricle.

[0077] The above-described methods for patient-specific simulation of cardiac electrophysiology and estimating patient-specific cardiac electrical parameters can be implemented on a computer using well-known computer processors, memory units, storage devices, computer software, and other components. A high-level block diagram of such a computer is illustrated in FIG. **12**. Computer **1202** contains a processor **1204**, which controls the overall operation of the computer **1202** by executing computer program instructions which define such operation. The computer program instructions may be stored in a storage device **1212** (e.g., magnetic disk) and loaded into memory **1210** when execution of the computer program instructions is desired. Thus, the steps of the methods of FIGS. **1**, **2**, **3**, **6**, **7**, and **8** may be defined by the computer program instructions stored in the memory **1210** and/or storage **1212** and controlled by the processor **1204** executing the computer program instructions. An image acquisition device **1220**, such as a CT scanning device, C-arm image acquisition device, MR scanning device, Ultrasound device, etc., can be connected to the computer **1202** to input image data to the computer **1202**. It is possible to implement the image acquisition device **1220** and the computer **1202** as one device. It is also possible that the image acquisition device **1220** and the computer **1202** communicate wirelessly through a network. In a possible embodiment, the computer **1202** may be located remotely with respect to the image acquisition device **1220** and may perform the method steps as part of a server or cloud based service. The computer **1202** also includes one or more network interfaces **1206** for communicating with other devices via a network. The computer **1202** also includes other input/output devices **1208** that enable user interaction with the computer **1202** (e.g., display, keyboard, mouse, speakers, buttons, etc.). Such input/output devices **1208** may be used in conjunction with a set of computer programs as an annotation tool to annotate volumes received from the image acquisition device **1220**. One skilled in the art will recognize that an implementation of an actual computer could contain other components as well, and that FIG. **12** is a high level representation of some of the components of such a computer for illustrative purposes.

[0078] The foregoing Detailed Description is to be understood as being in every respect illustrative and exemplary, but not restrictive, and the scope of the invention disclosed herein is not to be determined from the Detailed Description, but rather from the claims as interpreted according to the full breadth permitted by the patent laws. It is to be understood that the embodiments shown and described herein are only illustrative of the principles of the present invention and that various modifications may be implemented by those skilled in the art without departing from the scope and spirit of the invention. Those skilled in the art could implement various other feature combinations without departing from the scope and spirit of the invention.

1. A method for estimating patient-specific cardiac electrical properties from medical image data and non-invasive body surface potential measurements of a patient, comprising:

generating a volumetric patient-specific anatomical heart model and a patient-specific anatomical torso model from medical image data of a patient and an electrical coupling model between the patient-specific anatomical heart model and the patient-specific anatomical torso model;

estimating extra-cellular potentials on an epicardial surface of the patient-specific anatomical heart model from measured body surface potentials on a torso of the patient based on the electrical coupling model between the patient-specific anatomical heart model and the patient-specific anatomical torso model and estimating transmembrane potentials on the epicardial surface of the patient-specific anatomical heart model from the estimated extra-cellular potentials; and

estimating spatially varying patient-specific cardiac electrical parameters for the patient by:

initializing one or more cardiac electrical parameters of a computational cardiac electrophysiology model over the volumetric patient-specific anatomical heart model from the estimated transmembrane potentials on the epicardial surface of the patient-specific anatomical heart model;

simulating cardiac electrophysiology over time at a plurality of nodes in the volumetric patient-specific anatomical heart model using the computational cardiac electrophysiology model, and

adjusting the one or more cardiac electrical parameters of the computational cardiac electrophysiology model over the volumetric patient-specific anatomical heart model based on the estimated transmembrane potentials on the epicardial surface of the patient-specific anatomical heart model, and simu-